Fishery Data Series No. 94-26

Precision of Ages Estimated From Scales for Rainbow Trout in Bristol Bay, Alaska

by

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ABSTRACT

Precision of ages was estimated in three replicates among six readers from scale samples of rainbow trout *Oncorhynchus mykiss* of two different life history types, lacustrine and riverine. Logistic regression was used to examine the affect of experience level on the probability of repeating estimates among replicates. Analysis of variance models were used to examine the difference in mean modal age estimates among readers. Experience was found to be related to the probability of repeating estimates among replicates for riverine rainbow trout, but not for lacustrine rainbow trout. Mean modal ages varied significantly among readers, but the variation was not found to be related to experience. A procedure for reading rainbow trout scales is proposed which attempts to minimize both between and within-reader aging variability.

KEY WORDS: rainbow trout, *Oncorhynchus mykiss*, age, precision, scales, mean modal age, lacustrine, riverine.

INTRODUCTION

Rainbow trout stocks in Southwest Alaska are managed under the guidance of the Southwest Alaska Rainbow Trout Management Plan. The overriding philosophy of the plan is one of conservative management for wild stocks. The plan directs the Alaska Department of Fish and Game (ADF&G) to manage rainbow trout stocks to maintain historical size and age composition. Historical perspectives are gained through a series of estimated ages from scales collected over many years (Minard and Dunaway 1991); additional scale samples are collected periodically to detect changes in age compositions.

Age composition has routinely been estimated from scales. Since age estimation from scales is critical to the management of the area's rainbow trout stocks, estimates of precision associated with this aging method should be known. Additionally, since personnel associated with the management of rainbow trout fisheries will change over time, management will suffer if such change alters the age composition estimates of rainbow trout populations.

To counteract the possible affects of changes in management personnel on age estimates, a standardizing procedure for age estimation, or "reading," of rainbow trout scales is required. The standardization of rainbow trout scale age estimation can be accomplished by minimizing: (1) within-reader age estimation variability, and (2) between-reader age estimation variability. Minimizing within-reader variability can be accomplished through the use of multiple readings of each scale to obtain modal ages. Minimizing between-reader variability can be accomplished through the use of a training program which teaches scale readers standard criteria (Appendix A) for age estimation of rainbow trout scales.

In this study, the within-reader precision of age estimates from scales was evaluated for six trained scale agers (scale readers) chosen according to their experience reading fish scales. Estimates of the probability of repeating ages for fish between replicates, and the probability of obtaining a modal age across replicates were used as measures of within-reader precision. The between-reader precision of age estimates was evaluated by analyzing the mean modal age of each sample between readers. Each reader who participated in this experiment was trained to age rainbow trout scales according to standard criteria.

The drainages of Bristol Bay support populations of rainbow trout that predominantly utilize lacustrine habitat, and populations that predominantly utilize riverine habitat. These different populations have different life histories which generally allow the lacustrine populations to produce larger fish at age (Minard and Dunaway 1991). Because lacustrine rainbow trout generally grow faster than riverine rainbow trout, they are presumably more easily aged. This study addresses aging precision of both forms in separate experiments.

Objectives

1. To test the hypothesis that ages estimated from scales of lacustrine rainbow trout are the same among trained technicians such that a difference of one year can be detected with probabilities of a Type I and Type II error of 0.05 and 0.1, respectively.

2. To test the hypothesis that ages estimated from scales of riverine rainbow trout are the same among trained technicians such that a difference of one year can be detected with probabilities of a Type I and Type II error of 0.05 and 0.1, respectively.

METHODS

Scale Sample Selection

Scales from two populations of lacustrine rainbow trout were merged, sorted by fork-length, and divided into six equal length intervals to form the lacustrine data set. Ten samples (fish) were randomly drawn from each of the six length intervals to create a 60 fish lacustrine experimental data set. An additional five samples were randomly selected from each of the six length intervals to create the lacustrine half of the training data set. In this manner, the lacustrine data set was sampled to form the lacustrine experimental data set (60 fish), and the lacustrine half (30 fish) of the training data set. These same procedures were repeated to select the 60-fish riverine experimental data set, and the riverine half of the training data set. The 60-fish training data set was formed by merging its lacustrine and riverine halves. Any samples exhibiting extreme regeneration were removed from the experimental data sets and alternates randomly selected from the appropriate length interval.

The one, two, or three scales originally collected from each fish were impressed under heat on individually numbered acetate cards. The number on each card was used as a link to information about the specific fish.

Training Program

Six readers were chosen according to their scale reading experience: two with no experience in estimating the age of fish from scales; two with experience reading scales, but not with scales from rainbow trout; and two with experience reading rainbow trout scales. Each reader was trained before participating in this study. Training began with a manual for study and reference (Appendix A). The manual specifies the criteria to be used in detecting annuli on scales from rainbow trout in Bristol Bay. The criteria specified in the manual were reviewed and approved by several ADF&G personnel intimately familiar with rainbow trout scale interpretation. Training continued in "one-on-one" sessions with an experienced instructor where the reader examined and estimated age from the scales contained in the training data set. The reader was told the date and location of sampling, as well as the length of the fish when sampled. When the instructor believed the reader was able to accurately apply the criterion for annuli recognition specified in the training manual, training was completed. Microfiche projectors were used to inspect acetates at 40x.

Experiment

Between- and within-reader aging precision was estimated for both the lacustrine and riverine experimental data sets using six trained readers. Readers estimated the age of each fish in the data sets a total of three times (three replicate readings). Each reader estimated the age of each fish within a replicate only once, such that no re-aging was allowed. Before a scale was aged, the reader decided whether the scale was illegible due to regeneration (Appendix A). If the scale was judged to be legible, an age was estimated. If judged to be illegible, the scale was labeled illegible and no age was estimated. All samples judged illegible by any of the readers during any of the replicates were excluded from the experiment. The order in which the scales were read was changed between replicates to prohibit memorization of age estimates. During each replicate, the reader was provided with the location and collection date for each scale sample. There was no communication among readers about their estimates until after the experiment was completed.

Data Analysis

Within-Reader Precision:

If reading scales is a reliable means of estimating the age of rainbow trout, there should be little random error in assigning ages. Such random error can be detected through blind replication of estimates if error is measured as the probability of any two replicated estimates matching (repeatability). A good reader will have a high repeatability; a poor reader will have a low repeatability. The repeatability for a reader in this study was estimated as:

$$\hat{p}_r = \frac{\sum_{i=1}^{n} y_{ri}}{3n} \qquad (1)$$

where $\hat{p}_r$ is the probability of any two replicate estimates by a reader matching (repeatability), y_{ri} is the number of successful matches in three replicates from the *ith* fish by the *rth* reader, and n is the number of fish in the study. Division by three is included in Equation 1 because, for each fish, there are three possible matching pairs in the three replicates used in this study.

Another way to assess within-reader precision is to tally those fish for which a reader has a modal estimate of age. In three replicates per fish, any match between two replicates creates a mode; no matches mean no modes. The relationship between the probability of assigning a fish a modal age and the probability of matching replicated age (repeatability) is estimated as:

$$\hat{p}_r^* = 1 - \left(1 - \hat{p}_r\right)^3 \qquad (2)$$

where $\hat{p}_r^*$ is the probability of a reader assigning a fish a modal age.

Repeatability in estimates of age can also be a function of the fish. The probability of any two replicated estimates being repeated for a fish is a measure of its desirability as a sample. This probability was estimated as:

$$\hat{p}_j = \frac{\sum_{r=1}^{6} y_{ri}}{3(6)} \qquad (3)$$

where $\hat{p}$ is the probability of any two replicate estimates matching for a fish.

Between-Reader Precision:

A two-way, parametric analysis of variance (ANOVA) with replication was used to test each of the objective hypotheses. Each fish was considered an exogenous factor (block) and each reader a separate treatment (a random effect). Replications were used to estimate sampling error in the ANOVA. The null hypothesis for this ANOVA is that all readers produce the same modal average of estimated age over the fish in the study; the alternative is that this modal average of estimated age is different for at least one reader. Conditions for the accurate use of these procedures were that (1) deviations between actual estimates and their predictions from the ANOVA (ε) are normally distributed with mean 0 and common variance σ^2, and (2) the ε is mutually independent. The ε in other, similar studies (Baker and Timmons 1991; Merritt and Fleming 1991; Pearse and Hansen 1992; Sharp and Bernard 1988) have been (or nearly have been) normally distributed around 0. Logarithmic transformations of data were used to equalize the variances. The ε is assumed to be mutually independent since the study design minimized the possibility of the first replicate reading influencing the values of subsequent readings.

RESULTS

After the data sets were adjusted by removing samples which had been judged to be illegible by any reader in any replicate, the resulting sample sizes were 52 and 45 fish for the lacustrine and riverine experimental data sets, respectively.

Within-Reader Precision

Estimated probabilities of a reader repeating an estimate ($\hat{p}_r$) were not high, ranging from 0.30 to 0.62 for rainbow trout from lakes and from 0.33 to 0.59 for rainbow trout from rivers (Table 1). Table 2 lists the observed numbers of fish for which a reader assigned a modal age in this study.

Experience made no difference in the probabilities of repeating estimates of age for lacustrine rainbow trout ($0.90 > P > 0.75$), but did for riverine rainbow trout ($0.025 > P > 0.01$). Logistic regression of the proportion of fish in the study with modal ages was used to test the hypothesis that experience of readers is related to their consistency in estimates (Table 3). The deviance is a measure of the deviation between the fitted model and a logit transformation of the fraction of fish with matched replicates. The difference in deviances for models differing by only one term is distributed as a χ^2 statistic with 1 degree of freedom. The terms "R" and "(ER)" correspond to the effects of readers and to the interaction of the effects of readers and their experience.

Table 1. Probability of repeating age estimates between two replicate readings (repeatability).

Reader	Lake	River	Experience
A	0.38	0.44	No experience
B	0.32	0.52	No experience
C	0.30	0.59	Experience, but not w/ rainbow trout
D	0.46	0.33	Experience, but not w/ rainbow trout
E	0.62	0.59	Experience w/ rainbow trout
F	0.40	0.55	Experience w/ rainbow trout
Average	0.41	0.50	

Table 2. The observed numbers of fish for which a modal age was estimated.

Reader	Lake	River	Experience
A	38	37	No experience
B	40	40	No experience
C	41	41	Experience, but not w/ rainbow trout
D	45	32	Experience, but not w/ rainbow trout
E	52	43	Experience w/ rainbow trout
F	41	42	Experience w/ rainbow trout
Total	52	45	

Table 3. Logistic regression of the proportion of fish with modal ages by reader and reader-experience interaction.

Model	Deviance	Difference	df	Probability of a Type I Error
LAKES				
β_o	25.4			
$\beta_o + \beta_1 R$	19.6			
$\beta_o + \beta_1 R + \beta_2 (ER)$	19.5	0.1	1	$0.90 > P > 0.75$
RIVERS				
β_o	15.2			
$\beta_o + \beta_1 R$	13.5			
$\beta_o + \beta_1 R + \beta_2 (ER)$	8.0	5.5	1	$0.025 > P > 0.01$

The same method was used to test the hypothesis that repeatability in replicate estimates is the same for rainbow trout from lakes and rivers (Table 4). The $\hat{p}_r$ averaged across readers is 0.41 for lacustrine rainbow trout and 0.50 for riverine rainbow trout (Table 1). If the proportion of fish in the study with modal ages is used in the test as the measure of repeatability, the difference is not significant. The regression indicates that ages of rainbow trout are no more difficult to estimate from scales from lacustrine fish than from riverine fish ($0.25 > P > 0.10$).

Since repeatability is also influenced by the desirability of a particular fish as a sample, the probability of repeating an age for each fish was estimated. Estimated probabilities averaged over readers of two replicates matching for a fish ($\hat{p}$) were highly variable for rainbow trout from both lakes and rivers (Figure 1), but showed no pattern with size of fish. This lack of a trend indicates that repeatability of estimates is not a function of size or by implication, age of rainbow trout.

Between-Reader Precision

Estimates of mean age of fish among readers ranged from 6.6 to 9.0 years for fish from lakes and from 4.6 to 6.1 for fish from rivers (Table 5). For rainbow trout from lakes, the two readers with moderate experience anchored the extremes of the range; for rainbow trout from rivers, an inexperienced reader and a reader with moderate experience anchored the range.

Two parametric analyses of variance (ANOVA) were used to test the objective hypotheses that mean modal age was the same among trained readers (Table 6). The ANOVAs were blocked designs (fish were blocks) with nested main effects (readers within experience) and subsampling (replicates). For both groups of fish, the effect of experience on the variation of estimated ages in the study was not significant ($P > 0.77$ and $P > 0.83$ for lacustrine and riverine rainbow trout, respectively) while the effect of readers was significant ($P < 0.001$). This outcome indicates that mean modal ages estimated from scales are not the same among trained technicians and that the experience of readers or limited size of the experiment are unlikely explanations for the observed range of means. Furthermore, these results indicate that ages estimated from scales of both lacustrine and riverine rainbow trout are not the same among trained technicians such that a difference of one year can be detected with the probabilities of Type I and Type II errors identified in the objectives.

Histograms of the modal ages as assigned by the six readers show varying patterns (Figure 2). Since there is a monotonic relationship between size and age, the frequency distribution of estimates should reflect the frequency distribution of lengths of the fish used in the study. Tables 7 and 8 are frequencies of modal ages for each fish for each reader aligned by length of fish.

DISCUSSION

Repeatability and Estimates of Mean Modal Age

Repeatability of estimates of age was highly variable among readers ranging from 30% to 62% (Table 1). For lacustrine rainbow trout, repeatability was

Table 4. Logistic regression of the proportion of fish with modal ages averaged across rainbow trout life histories by reader, reader-experience interaction, and rainbow trout life history type (lacustrine or riverine).

Model	Deviance	Difference	df	Probability of a Type I Error
β_o	43.1			
$\beta_o + \beta_1 R$	35.8			
$\beta_o + \beta_1 R + \beta_2 (ER)$	32.8			
$\beta_o + \beta_1 R + \beta_2 (ER) + \beta_3 T$	30.3	2.5	1	$0.25 > P > 0.10$

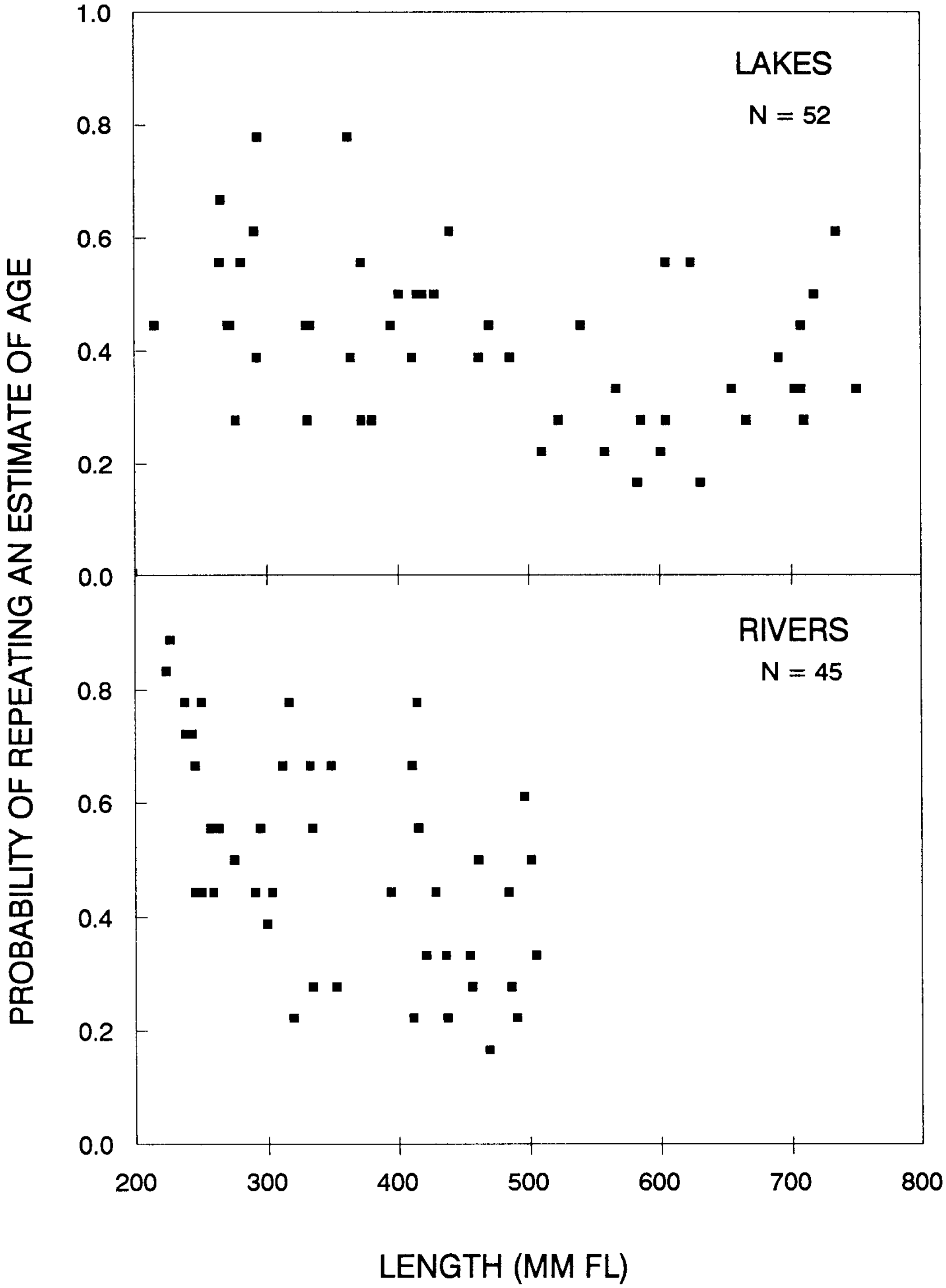

Figure 1. Probability of repeating estimates through replicate readings of scales from individual rainbow trout from selected Bristol Bay waters. Probabilities are averaged over readers.

Table 5. Mean age by reader and rainbow trout life history type.

Reader	Lake	River	Experience
A	7.0	5.6	No experience
B	7.8	4.5	No experience
C	6.6	4.6	Experience, but not w/ rainbow trout
D	9.0	6.1	Experience, but not w/ rainbow trout
E	8.3	5.1	Experience w/ rainbow trout
F	8.0	6.1	Experience w/ rainbow trout

Table 6. Analysis of variance comparisons of mean modal age estimates among readers and experience.

Source of Variation	df	Sum of Squares	Mean Square	F	Probability of a Type I Error
LAKES					
Fish	51	5160.4	101.2		
Experience	2	88.6	44.3	0.28	0.77
Reader(Experience)	3	475.5	158.5	29.2	< 0.0001
Error (Experimental)	12	65.2	5.4		
Error (Sampling)	867	708.5	0.8		
RIVERS					
Fish	44	2900.1	115.4		
Experience	2	37.6	18.8	0.18	0.84
Reader(Experience)	3	304.7	101.6	26.0	< 0.0001
Error (Experimental)	12	46.9	3.9		
Error (Sampling)	746	476.7	0.6		

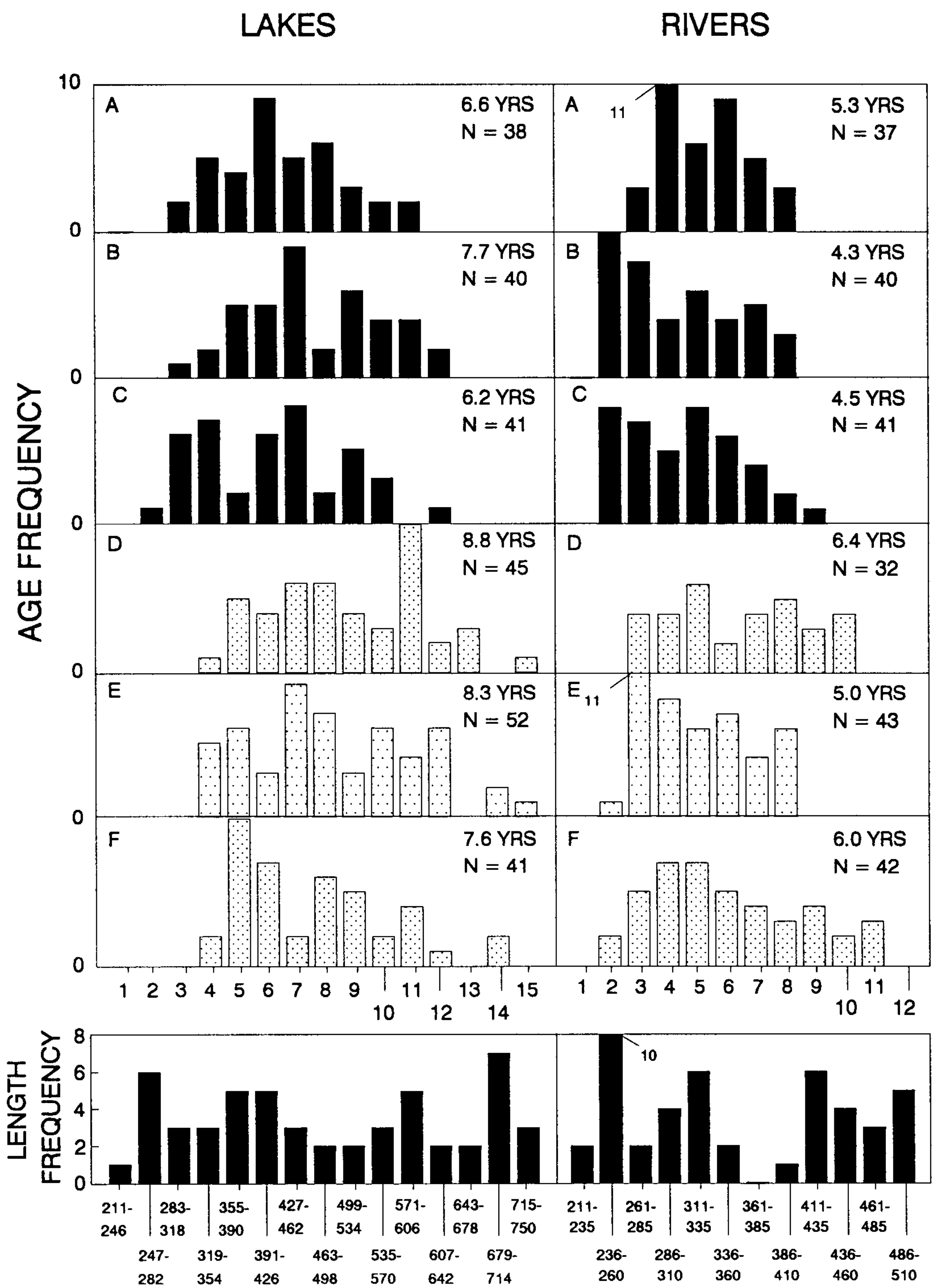

Figure 2. Length frequencies and estimated modal ages of rainbow trout from selected Bristol Bay waters. Average of modal ages for all fish along with the number of modal ages represented in each histogram are in the upper right corner of all panels. A character distinguishing individual readers is in the upper left corner of each panel.

Table 7. Frequency of modal ages of 52 rainbow trout from lakes in the Bristol Bay Area. Ages are "modal" when two or more replicate readings for a fish match by a single reader. A reader is "confused" when he/she failed to repeat an estimate for a fish.

#	Length	Age 2	3	4	5	6	7	8	9	10	11	12	13	14	15	Number of Confused Readers
46	214	1	2	2	1											
44	264		3	2		1										
50	265	1	2	3												
48	270	1	1	4												
40	272	1	1	3	1											
39	276	1	1	2	1											1
51	280	1	3	2												
52	290	1	2	2	1											
45	292		1	3		1										1
37	293		2	3	1											
43	330				3	3										
41	331		1		2	1	1									1
42	333		1		1	2										2
21	362		1		5											
49	364				2	2	1	1								
23	372	1	1	3	1											
1	372	1		1		1	2									1
38	380				3	2										1
18	395				2	1	1									2
36	401			2	2	1	1									
35	411				1	3	1									1
7	415				1	3	1									1
15	419				1	1	3									1
22	428			1	1	2	1									1
20	440				2		3									1
24	462					3		1	1							1
34	470				3	3										
47	486					1	1		1	3						
6	510					1	1	1		1	2					
12	523						1			2						3

-continued-

Table 7. (Page 2 of 2).

#	Length	Age 2	4	5	6	7	8	9	10	11	12	13	14	15	Number of Confused Readers
11	540				1		3	2							
8	558						1	1	1	1	2				
17	567						1	2		1					2
32	583					1			1	1	3				
14	586					1		1	1	2					1
26	601					1		1	1	1	2				
19	605					1	2								3
29	605					1	1	3	1						
10	624						1	3	1	1					
27	631							1	1	1	3				
2	655							1	2	1					2
33	666								2	1	2	1			
25	691							1	1	1	1	1	1		
9	703							2		1	1				2
30	705								2		2	1	1		
28	706						1	3	2						
13	708							1		3	1	1			
4	708									1	1		2		2
3	710						1		1	1	2				1
31	718					1	1	1		2					1
5	735									1	1		1	2	1
16	750					1			1	1	1	2			

Table 8. Frequency of modal ages of 45 rainbow trout from rivers in the Bristol Bay Area. Ages are "modal" when two or more replicate readings for a fish match by a single reader. A reader is "confused" when he/she failed to repeat an estimate for a fish.

		Age											Number of Confused Readers
#	Length	2	3	4	5	6	7	8	9	10	11	12	
38	223	2	2	1									1
31	226	1	3	2									
32	237	3	3										
25	238	3	1	1									1
29	243	2	2	1									1
33	245	2	1	3									
16	245				2	3	1						
45	250		5	1									
41	250	3	3										
3	257		1	4	1								
11	259		3	1	2								
23	260	1	2	3									
1	263	1	4		1								
4	275		3	2									1
28	291				5	1							
43	295	2		2	2								
13	300		2	1	2								1
19	304	1	1	1	2		1						
39	312				5	1							
24	317			3	3								
9	320		1	2	1								2
37	333			3	1	2							
44	335			1	3	1	1						
8	335		1	1	1								3
30	349			4	1	1							
35	353			1	2	2							1
36	395						2	3	1				
15	411					4	1	1					
26	412						1	2	1				2
27	415					4	2						

-continued-

Table 8. (Page 2 of 2).

#	Length	Age											Number of Confused Readers
		2	3	4	5	6	7	8	9	10	11	12	
14	416					2	1		1				2
21	422				1	2	2	1					
22	429					2	3	1					
10	437				2	1	1						2
12	438						2	2					2
18	455			1	2		1						2
17	457						1	2	2				1
20	462					3		2					1
2	470						1	1	1				3
6	485						2	1	1				2
7	487					3				1	1		1
34	491						1	1		2			2
42	497					1	2	1		1			1
40	502							2	1	1	1		1
5	506							2		1	1		2

not found to be related to the experience of the readers. For riverine rainbow trout, repeatability increased with increased experience. This suggests that scales from riverine rainbow trout may be more difficult to read than scales from lacustrine rainbow trout. However, when life history type was included in the model to predict repeatability, the affect was insignificant, indicating that riverine and lacustrine types were equally difficult to read. The lack of a consistent trend among these analyses does not allow an objective judgment as to the relative difficulty in reading scales between lacustrine and riverine types.

Fish size, and by implication age, was not found to be related to repeatability. This result indicates that only superficial benefits in repeatability would be realized by the common technique of pooling all ages into one category above some critical age.

Estimates of mean modal age varied significantly among readers for rainbow trout from both the riverine and lacustrine samples. This variation in estimates was not found to be related to experience. Given this result, the training program instituted for this study is insufficient compensation for the differing abilities of readers, and experience as defined in this study is insufficient compensation in the effectiveness of the readers. These results might also be interpreted to mean that the ability to consistently recognize patterns in rainbow trout scales may be a skill which can not be learned through experience.

RECOMMENDATIONS

Given the major results of this study, the following procedures for aging rainbow trout scales from Bristol Bay drainages should be adopted:

Scale age should be estimated three times in blind replication with modal age being used as the correct estimate. All fish with no modal age after three replications should be ignored in estimating statistics for the population.

In order to minimize within-reader age estimation variability, personnel responsible for reading rainbow trout scales should have demonstrated the ability to repeat estimates of age with a probability of at least 60%. A reader with 60% repeatability will fail to assign a mode on only 6% of fish given three replications. Additionally, readers with high repeatability will assign modal ages which more accurately describe the central tendency of a distribution of estimated ages for a particular fish.

Though the most effective means of minimizing between-reader age estimation variability is to require that a single reader estimate ages for all Bristol Bay rainbow trout in the future, inevitable changes in management staff preclude this option. A practical means of minimizing this variability begins with the development of a data set which includes scales and ages estimated through consensus by a group of highly trained scale readers. This data set is then used as a standard with which potential scale readers are evaluated. Only persons with the demonstrated ability to age precisely (high repeatability) and accurately (against the standard) should read scales in the future. Furthermore, the training manual should be improved and readers should refer to it periodically to assure that criterion for annuli recognition remain constant.

Since the preceding procedure in part identifies an aging method by which only a particular subsample (fish with modal age) are used to determine age composition of a population, an experiment should be conducted to identify what affect this subsampling has on the estimate of age composition. If the effect is random and all age segments of the population are affected equally, then subsampling based on modal age would not affect the estimate of age composition. If the effect is not random and some age segments of the population are affected more than others, then subsampling based on modal age is likely to affect the estimate of age composition.

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APPENDIX A

TRAINING MANUAL FOR RAINBOW TROUT SCALE READERS

Appendix A. Training manual for rainbow trout scale readers.

Fish scales have long been used to estimate the age of fish (Alvord 1954). Scales can be collected quickly and in large numbers without killing or severely harming fish. Preparation and estimation of approximate age from scales is relatively easy and inexpensive compared to the processes required for aging other bony structures. For these reasons, ADF&G prefers to use scales for age estimation in its monitoring and management of rainbow trout stocks in Southwest Alaska.

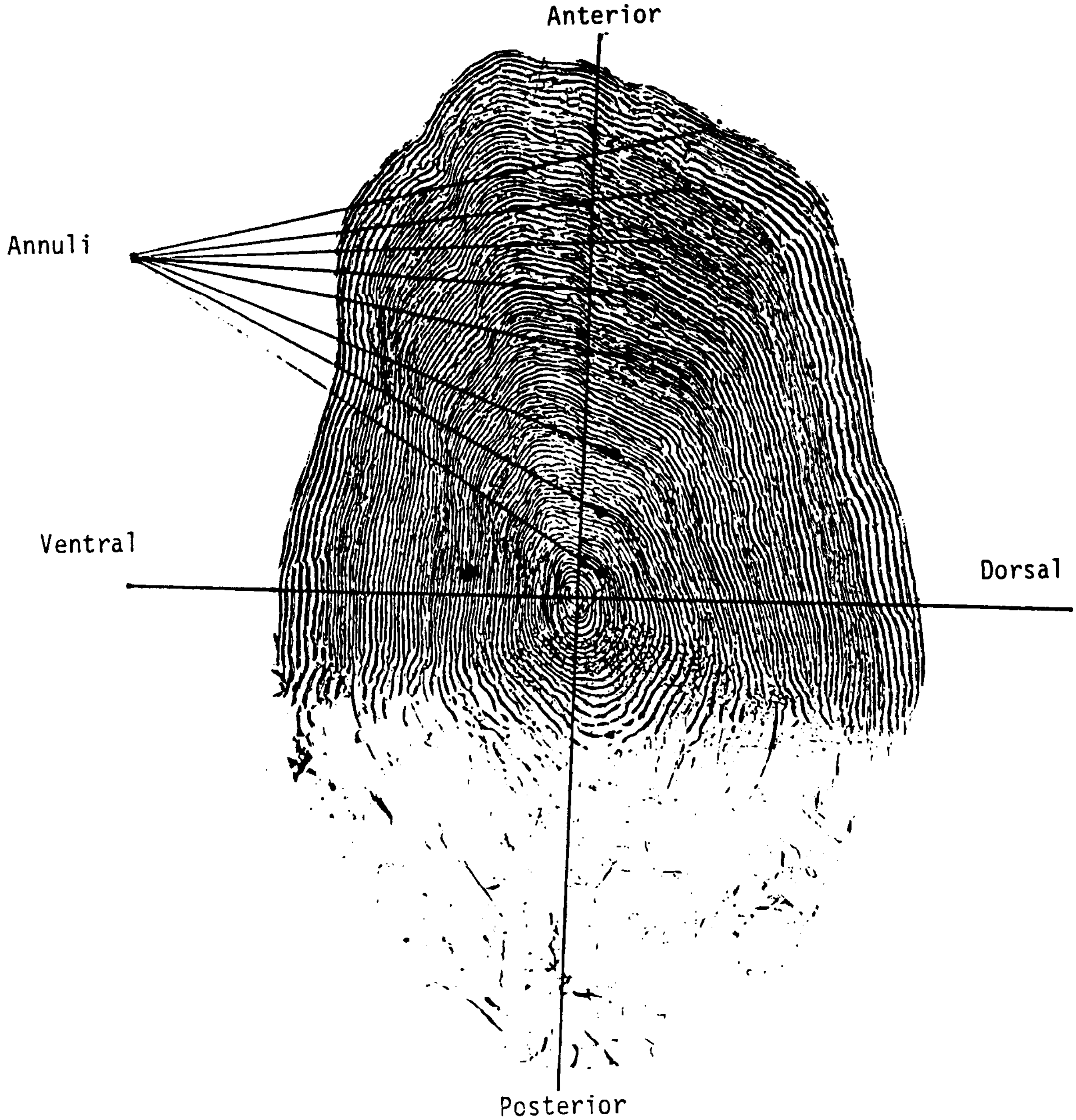
Estimating fish age from scales can be a highly subjective process. A consistent method of collecting and "reading" scales is required for obtaining useful age data. The historical collection of Southwest Alaska rainbow trout scales (over 30,000 samples) is believed to have been aged consistently because the vast majority of the age estimations were made by only two ADF&G employees, Richard Russell and Dan Bosch (Minard and Dunaway 1991). The following methods were adopted to assure that age estimations made by future rainbow trout scale readers are consistent with the historical data base.

Criteria

Some general observations of fish scale growth and development followed by specific interpretations of characteristics found in Southwest Alaska rainbow trout scales were combined to form the following set of criteria:

Individual scale growth begins with the formation of the focus, or area enclosed by the first circulus (Mosher 1969). The scale grows outward from the focus with the greatest growth occurring toward the anterior margin of the scale. Fine ridges called circuli are laid down in a circular pattern around the focus as the scales grow and many circuli are added to the scale each year. When magnified, the circuli appear as dark rings around the scale. The first few circuli completely encircle the focus. After the complete circuli, the others appear as arcs that tend to end abruptly at the junction with the exterior (posterior) portion of the scale (Mosher 1969). In some species of salmon and trout, the bases of the circuli may not end abruptly, but may extend posteriorly for varying distances, or the circuli may be broken or enlarged in this area (Mosher 1969; Lux 1971).

The growth rate of a fish is reflected in scale growth (Lux 1971). Circuli are widely spaced when fish growth is rapid and closely spaced when growth is slow. "Since fish continue to grow throughout their lives, this pattern [of annuli] is repeated each year" (Lux 1971, page 4). "The age of a fish is estimated by counting the number of annuli or year-marks."

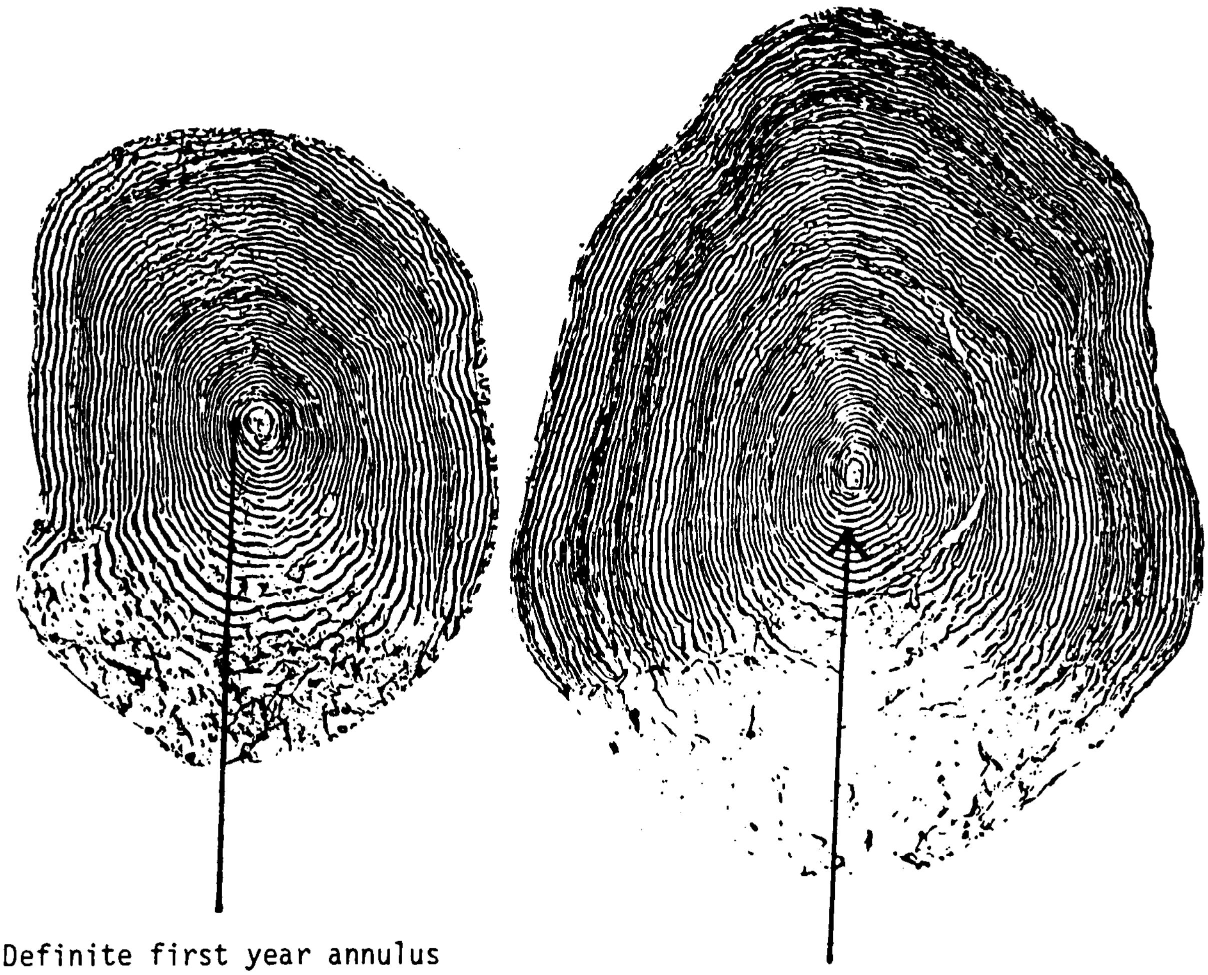


Annual mark or "check":

Under magnification, groups of closely packed circuli associated with annually reduced rates of growth appear as dark bands compared to groups of circuli generated during rapid growth. An annulus is defined as a concentrated group of broken circuli running forward from the posterior margin on one side of a scale around to the posterior margin on the other side. Age is estimated by counting annual marks on the anterior portion of the scale from the focus to the margin along a line approximately 30 degrees to the anterior-posterior axis of the scale. Nonspawning rainbow trout may produce detectable annuli in early spring when their annual growing season begins. Also, spawning rainbow trout may produce detectable annuli in early summer coincident with the beginning of their annual growing season after spawning (Appendix B).

Scale regeneration:

When a scale is lost, a replacement (regenerated) scale grows rapidly to reach the size of the original. Regenerated scales do not form circuli during the period of rapid growth and often appear clear, pebbly, or irregularly formed compared to the original scale. When the regenerated scale reaches the size of the original, further growth occurs and circuli are formed at the same rate as the surrounding nonregenerated scales. Since regenerated scales lack age and growth information prior to scale loss, ages estimated from regenerated scales are not reliable. Therefore, scales regenerated past the fourth or fifth circuli should not be used for age estimation.

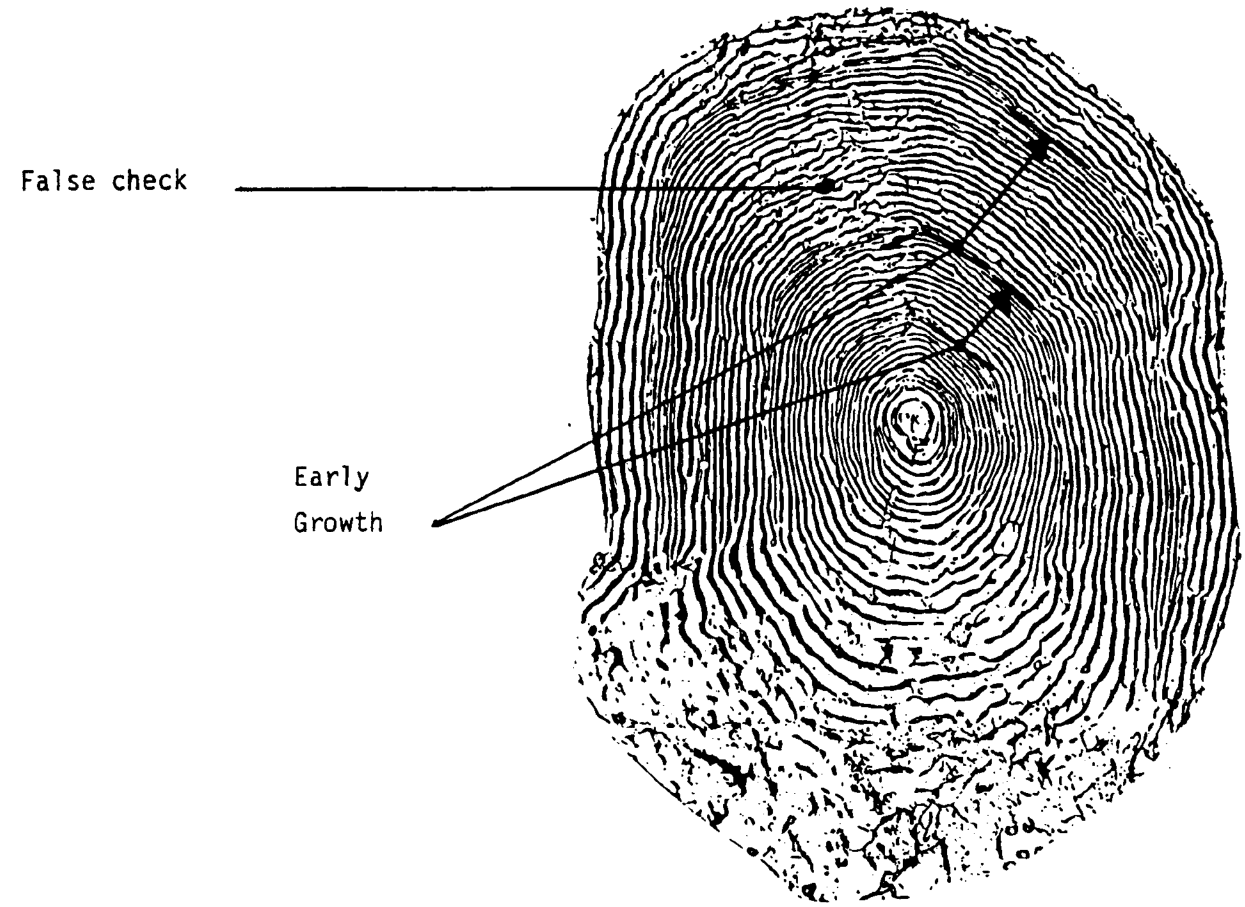


Definite first year annulus

No definite first year annulus

First annual mark:

Rainbow trout may not produce an annual mark their first year of life (Lentsch and Griffith 1987). If there is no distinct first year annulus within the first 20 circuli, an annulus is assumed to be within the seventh to fourteenth circuli.

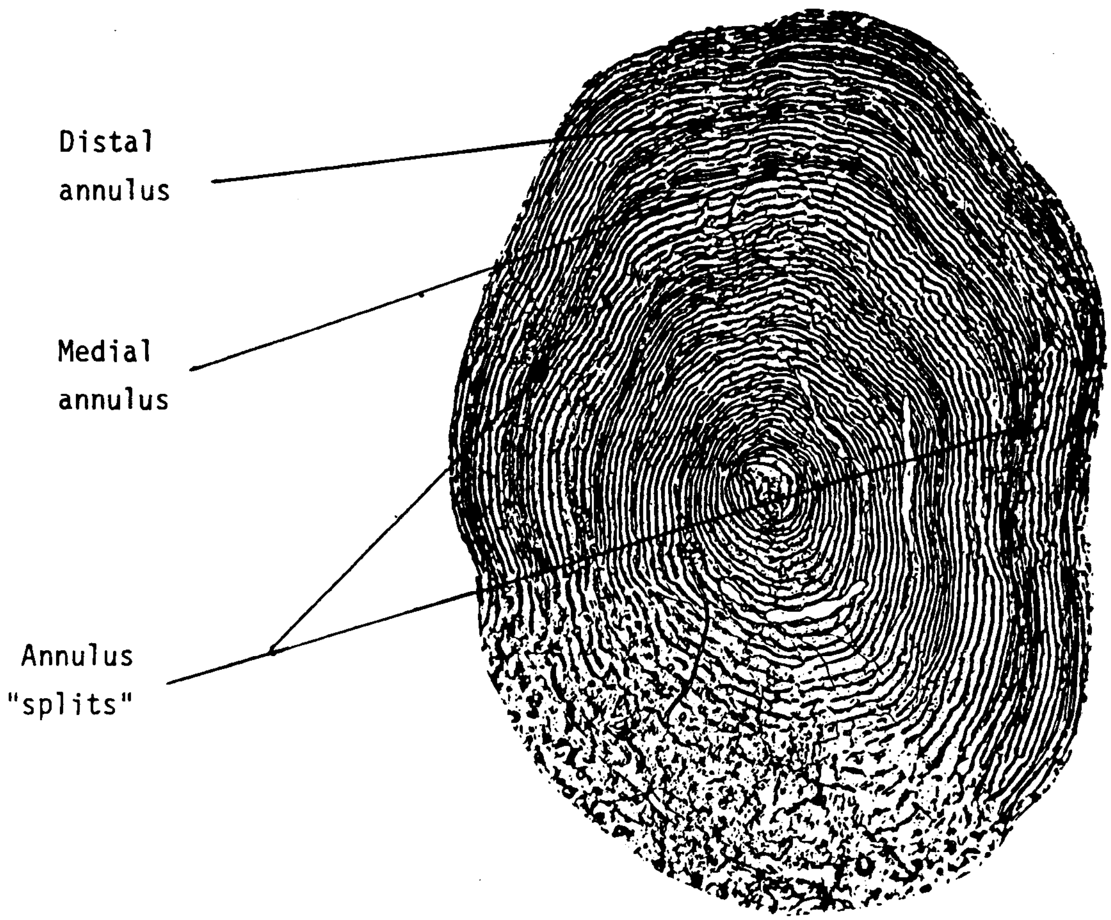


Early growth:

Often large bands of summer growth are observed between the second, third, fourth, and fifth annuli. Summer growth regions between subsequent annuli are generally smaller.

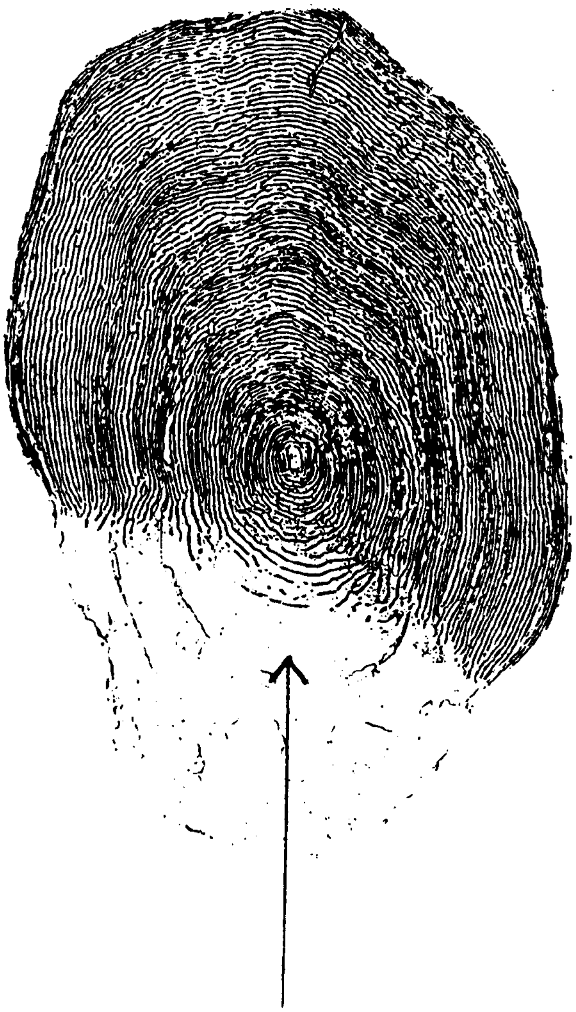
False "check":

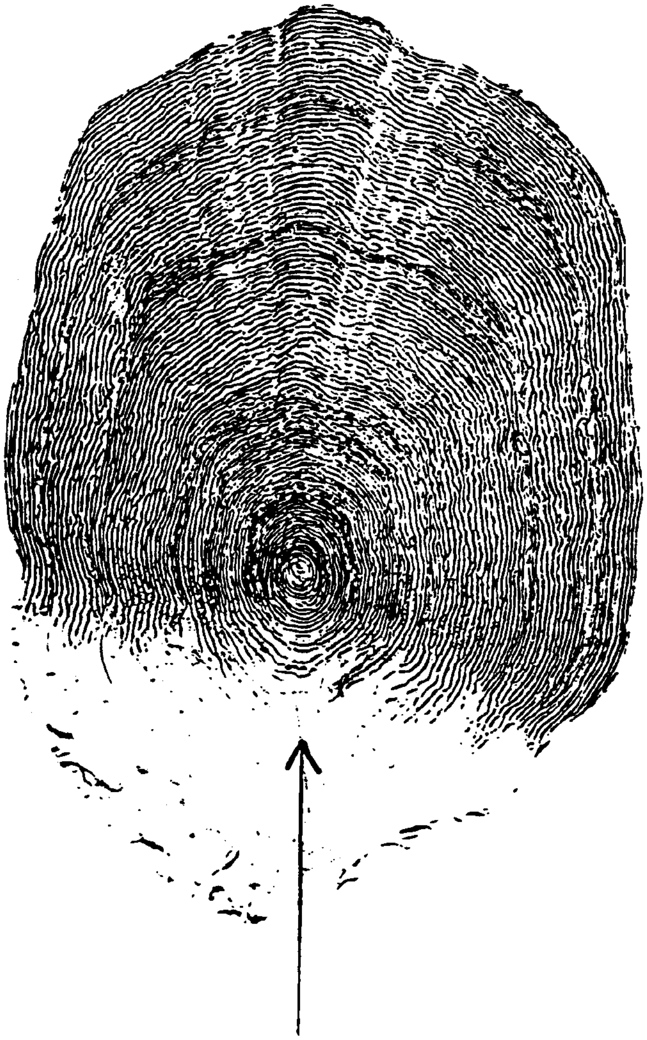
False annual marks may occur during a period of reduced growth, injury, or shock (Lux 1971). False checks can occur in rainbow trout and readers should be aware of their existence. Standard characteristics of false checks include thinner than normal annuli or annuli which are only visible to one "side" of the anterior-posterior axis of the scale.



Spawning mark or "check":

During spawning, rainbow trout tend to resorb the margin of their scales. Resorption may consume the scale through one, two, or zero annuli. However, since resorption is usually more pronounced on the dorsal and ventral margins of the scale, at least a portion of resorbed annuli usually remain on the anterior margin of the scale. After spawning is completed, fish begin growing and spawning year annulus deposition occurs. This new annulus is generally shaped atypically. It usually appears as one annulus along its dorsal and ventral portions, and "split" into two annuli along its anterior portion. Readers should recognize that of the "split" annuli, the more medially located annulus is last year's check, while the more distally located annulus is the spawning year check. This structure is called a spawning check and is interpreted as two years.





Spring sample with a check on the margin.

Spring sample without a check on the margin

Plus growth:

The growth occurring after the production of the last annulus until the collection of the sample is called "plus" growth. A reader must be aware when samples were collected to accurately interpret plus growth. For example, samples collected in the early summer will likely exhibit much less plus growth than those collected in the fall. Additionally, due to the presumed timing of annulus deposition in Southwest Alaska rainbow trout stocks, samples collected in the spring of the year must be read with additional care (Appendix B). If a spring sample exhibits significant plus growth and possibly some resorption, it is probably a sample from a spawning fish and should be aged as visible annuli plus one year. However, if a spring sample exhibits little or no plus growth and no apparent resorption, it is probably a sample from a nonspawning fish and should be aged as visible annuli with no additional years added.

APPENDIX B

CRITERIA USED AND CHARACTERISTICS OBSERVED WHEN DETERMINING THE AGE FROM RAINBOW TROUT SCALES COLLECTED IN SOUTHWEST ALASKA BEFORE 1990

Appendix B. Criteria used and characteristics observed when determining the age from rainbow trout scales collected in Southwest Alaska before 1990.

Developed by Dan Bosch, Alaska Department of Fish and Game, Dillingham, 1992

The purpose of these criteria is not to teach someone how to identify each annulus, but to help them interpret the three problem areas as I see them. I assume that the reader can identify an annulus. The three problem areas are as follows: (1) Identification of the first annulus, (2) spawning check interpretation, and (3) determination of the time of annulus formation. I believe these lead to the most error aging rainbows. Misinterpreting all these on one scale could lead to being off on the age of a fish by 3 years.

1. THE FIRST ANNULUS: Rainbow trout fry do not always lay down an annulus during their first year of life (Lentsch and Griffith 1987). Because of localized habitats and therefore different growth rates, age 0 and age 1 juvenile rainbows should be captured from each area to determine when the first annulus is laid down. With these young fish determine a range of number of circuli to the first annulus. Use this as your guide for each system to determine age 1. If young fish are not available try to be reasonable about the number of circuli before the first annulus i.e. probably 7-14 (give or take a few) depending on the system. If you are counting out 20 circuli to the first annulus you may be missing the first annulus.

2. SPAWNING CHECKS: I believe a spawning check occurs when the dorsal and ventral portions of a scale are reabsorbed but the anterior portion is not reabsorbed as rapidly. This is a typical pattern of scale reabsorption and most frequently associated with spawning fish. The "sides" of a scale can be reabsorbed through one, two, or no annuli. The fish will start to grow again after recovering from spawning; growth placed back on the scale then leaves a crescent shape on the anterior portion of the scale. Be careful interpreting these checks. Each spawning check may represent 2 years of growth and not 1 year as some believe. Example: The dorsal and ventral portion of the scale are reabsorbed through all of last year's growth to last year's annulus. This fish then starts to grow and lays down another annulus. Along the ventral and dorsal areas of the scale only one annulus is present, but on the anterior portion of the scale the two annuli form a crescent shape. I interpret this as 2 years. I have also seen this crescent shape on the anterior part of the scale without any annulus along the ventral and dorsal area. Spawning checks occur more frequently in areas like the Pak, the Wok, and the Copper River (as I recall). Interpretation of spawning checks usually requires a judgment call.

3. THE EDGE: Determining when a fish lays down an annulus during the course of the year is important. It has been my experience that trout not going to spawn that spring will lay an annulus down earlier in the season than a trout that will spawn that spring.

This is one reason for differences in the width observed in plus growth on scales collected during the summer and fall. Fish not spawning will be able to put more energy into maintenance and growth than a fish that is trying to produce gametic tissue. Rainbows not in spawning condition will lay an annulus down starting about April (the farther north the later this may be). Rainbows spawning that spring may not put an annulus down until late June. This means some fish may have a lot of seemingly unaccounted for plus growth in the spring, when in fact they haven't laid down last year's annulus yet. The "extra" plus growth observed on scales in late spring is more common in high productivity areas like Lake Iliamna tributaries (Talarik Creek etc.).